ZWICKER'S

INSTRUCTOR

FOR

MACHINISTS, FIREMEN AND YOUNG ENGINEERS

TO

PROCURE LICENSE.

ZWICKER'S

INSTRUCTOR

FOR PROCURING

STATIONARY

—AND—

Steam Engineers License,

—BY—

PHILIP HENRY ZWICKER,

PRACTICAL ENGINEER AND MACHINIST.

ST. LOUIS, MO.

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PREFACE.

The intention of this book, is to give correct and straightforward answers to all the legal questions, that any board of stationery Engineers may ask a candidate when undergoing examination for procuring Engineer's License; chosen with the view of saving the reader a long and tiresome search through numerous volumes after some point, and enabling him to get directly at the information desired, as special efforts have been made toward giving the information of such practical utility. Steam may be managed by a common sense rule, but if the laws which regulate its use are violated, it will make things very unpleasant.

No one is to blame for not being well informed on subjects of which he did not know where to obtain information; but, when once informed where it can be procured, if he fails to avail himself of the opportunity of so doing he deserves no sympathy. Hints and examples are also

given, intending to show how a great many practical improvements can be made by Engineers, Firemen and Owners of steam engines and boilers.

The importance of this book, is, to keep Engineers informed of their duty in regard to the Safety Valve, Engine, Boiler and Pump. With this book and what experience a man has, he can become a good Engineer. A man of plain education, studying this book, will find that it is simple and easily learned; also the only book explaining these things plainly.

Engineers should inform themselves of the safe working pressure of the Boilers in their charge, by calculating from the thinnest part of the shell. By the information to be derived from this book, a man can educate himself to become an Engineer without loosing any time learning the trade.

That this work may serve as a trustworthy instructor to the candidate, will be observed in the following questions and answers.

PHILIP H. ZWICKER,
Author.

ZWICKER'S
QUESTIONS AND ANSWERS
—FOR—
MACHINISTS, FIREMEN AND YOUNG ENGINEERS.

QUESTION. Are you a Mechanic?

ANSWER. Yes or No.

Q. Have you worked at finishing?

A. Yes or No.

Q. What kind of Boilers are there?

A. There are different makes; such as Flue, Tubular, Hanging-fire box, Upright, Cylinder and various other kinds, but the above named are most in use.

Q. What is a boiler made of and how composed?

A. A steam boiler is made out of steel or iron plates, the most in use is ⅜ and ½ inch charcoal iron 66,000 lbs. tensile strenght; these plates are run through a

rolling machine and rolled in a circle, then rivited together with two rows of rivets, because the strain is greater sidewise than endwise, the seams around the boiler are single riveted because the strain is not so great; the boiler is braced by different makes of braces, sush as crow foot, longitudinal braces, dome braces, side braces, etc. The eye is riveted to the head of the boiler, which head is generally made of ⅝ in. plates, the other eye is riveted to the side, top or dome of boiler; and they are put together by bolts with a split key to keep the bolt in place.

Q. How should a brace fit?

A. It should fit tight, for if it were loose it would be of no account.

Q. If you found a brace loose, what would you do and how would you tighten it?

A. By taking the brace out, heat it in the center, then upset it by jumping it endwise on a block of wood until it is the proper length.

Q. Why is a boiler braced?

A. For strength.

Q. What are Stay-bolts?

A. A Stay-bolt is a screw bolt, put through an outside and into an inside sheet so as to hold them, that they may not spread or collapse, such as a fire-box sheet and an outside shell, they are put together with stay-bolts so as to allow a water space between the two sheets.

Q. How is a stay-bolt made and put in?

A. They are made with one contiuous thread and screwed through the outside, then through the space between, then through the fire-box sheet and allowed to stick through $\frac{3}{16}$ in. so they can be riveted over each end so as to act as a brace, the space between the two sheets is called a water space.

Q. What is meant by corrosion?

A. It means wasting away of the iron of boiler plates by pitting, grooving, etc. There is internal and external corrosion; the acids and minerals in the water liberated by the heat, attack the boiler internally, and the sulpher which comes out of the coal has a strong attachment for the iron, and that attacks the outside.

Q. How would you find the water level when your boiler is foaming?

A. The proper way would be to shut down the engine and all valves connected with the boiler, cover fire with ashes, close the damper, then the water will quiet down, and the level of the water can be easily found. An engineer should know when lighting a fresh fire, never to force it, but let it heat gradually, so that all parts expand as near equal as possible; good judgement is needed. Boilers and steam-guages should be tested at least once a year.

Q. If you should take a wrench, and screw up a nut on a stud in a boiler, steam-chest, cylinder, or anywhere where steam may blow out, or should happen to break out, what would you do?

A. Simply make a hard wood plug and drive it in with a heavy hammer, leave it in until I could shut down and then repair it.

Q. What is the best way to clean a glass guage inside?

A. The best way, is to take a small piece of waste, and tie it to a strong thin

piece of stick and saturate the waste with soap or acetic acid, and pass down inside of tube, then blow through with steam, and the glass will be clean as new. Never touch the inside of a glass water guage with wire, if you do, it will crack. The best glasses are the Scotch brand, called Eureka.

Q. What clearance should a boiler have?

A. It should have about 4 or 5 in. all around from fire-line to fire-line, between the shell and bridge walls; and a boiler should have from 2 to 3 bridge walls so the fire and heat will hug the boiler; it also makes the coal burn cleaner and steams easier. The first bridge wall should be on the back end of the grate bars, and the others about 3 to 5 feet apart, according to the length of the boiler. Where the smoke returns through the flues, it should have about 1 or 1½ feet clearance. The bridge wall should lean toward the back.

Q. How should a boiler rest and what on?

A. The front end of the boiler should

rest on the fire front and the back end generally rests on a cast iron leg or two rollers to allow the boiler to expand equally. The mud drum should always hang free under all circumstances. Engineers should be careful in starting or stopping an engine with a high pressure of steam, because the rent in giving the steam in starting, and the sudden check in stopping, may cause such a pressure as to rupture the boiler. Engineers should see that their draft is not choked by ashes under the boiler, and that the outside of the boiler and inside of flues are kept clean, then they will have no trouble in keeping up steam.

Q. In case the throttle valve should get loose from the stem and prevent the steam from entering the valve chest, what would you do?

A. Close the valve next to the boiler, if there was one; if not, let the boiler cool down, then take the valve out and repair it.

Q. What different strains has a boiler?

A. To the flues or tubes, it has a crushing strain, to the shell a tearing strain.

Q. What causes boiler explosions?

A. There are various causes; such as low water, high pressure of steam, bad safety valve, foaming boilers and burnt sheets.

Q. Why would a foaming boiler cause an explosion?

A. It generally raises the water from the heated sheets, they become hot, the water falling back on them they crack and sometimes cause an explosion, a blistered sheet or a scaly boiler will also cause explosion by allowing the sheets to become burnt and weakened; also an untrue steam guage is very bad.

Q. What are the worst explosions?

A. The worst explosions are caused by high pressure and plenty of water; low water allows the iron to burn and crack, which weakens it, and when the cold water touches it, it does not take so much to burst.

Q. How would you know if your boiler had blistered sheets or was rotten?

A. By the hammer test; by taking a small hammer and going inside and out-

side of the boiler and seeing if it is all right by sounding it.

Q. How would you know by sounds?

A. By the different sounds it has; if it rings and sounds solid it is all right, but if it sounds dead, hollow or blunt there is something wrong.

Q. Would you strike the iron hard?

A. Yes, pretty hard.

Q. If you wanted to put a patch on a boiler, what kind would you put on, and which is the best, a hard or soft patch?

A. The hard patch; it is the most reliable and safest.

Q. Why not put on a soft patch?

A. Because they are not reliable and are dangerous.

Q. What is the difference between a hard and soft patch?

A. A hard patch is a patch where the piece is cut out of the boiler and rivet holes are drilled or punched through, then the patch is riveted on, chipped, corked and made water and steam tight.

Q. What is a soft patch?

A. A soft patch is put over the plate

that needs patching, and put on with ⅝ or ¾ in. countersunk screw bolts and a mixture of red lead and iron borings to put between the patch and boiler; the piece of sheet in boiler is not cut out for a soft patch as in a hard patch, consequently the patch is burnt, as the water in the boiler can not come in contact with the patch.

Q. What is the best, drilled or punched holes?

A. Drilled holes are the best.

Q. Why?—A. Because the fiber of the iron is not disturbed as in punching; in drilling, the iron is cut out regular, in punching, it is forced out at once.

Q. What should be the proper rivets for certain sized sheets, and how far apart?

A. The rivets should be ⅝ and ¾ in., and 1½ to 1¾ in. apart.

Q. Before shutting down at night, what would you do?

A. Pull out the fire, pump up to the third guage and close the glass guage cocks, so in case the glass should happen to get broken during the night, the water would not escape.

Q. What would you do the first thing in the morning on entering the fire-room.

A. See how much water was in the boiler by trying the guage cocks, and open the glass guage valves, then start the fire to raise steam.

Q. Why do you try the guage cocks, and not trust to the glass guage?

A. Because the water pipe connecting the glass guage with the boiler is liable to become stopped up with mud, consequently the glass would not show a true level of water. The glass guage should be blown out five or six times a day to insure safety, but never depend on the glass alone.

Q. If you found too much water in the boiler during the day, what would you do?

A. Open the blow-off valve and let out water to the second guage. An engineer should be very careful when blowing out water, when he has a hot fire in the boiler furnace, as the water leaves very fast and may blow out too much; good judgement should be used.

Q. How would you clean the flues or tubes of a boiler.

A. By either blowing steam through them or using a flue cleaning brush.

Q. How are flues or tubes cleaned with steam?

A. Some boilers have an inch and a half pipe with a valve attached, also branch pipes of smaller dimensions, leading from the 1½ in. into the back end and into the flues; others have a hose attached to the front end leading from the steam drum, so flues or tubes can be blown out from front end. Cleaning by brush is best.

Q. How often would you clean out the flues, and when?

A. Once a day, and in the afternoon. Sometimes in the morning after raising steam.

Q. How would you clean a boiler?

A. Let out all the water through the blow-off valve, then take out man-head, hand-hole and mud-drum heads, then take a short handle broom, a candle or torch, small hand pick, a scraper made out of an old file flattened on the end and bent to suit, and a half inch square iron twisted link chain, about 3 feet long, with a ring

at each end to answer for a handle, place chain around the flue and work the chain to get the scale off the bottom of the flues, use the pick and scraper to pick and scrape off all that can be seen on top of flues, and the bottom and sides of shell; then wash out into the mud-drum, clean out and put in the mud-drum and hand-hole heads, fill up to top of flues, then put in man-hole plate, and fill up to second guage ready for raising steam.

Q. Could a boiler not be blown out?

A. Yes.

Q. How much pressure would you allow? A. About 20 or 30 lbs.

Q. Why not more pressure?

A. Because the heat would be so great that the expansion and contraction would not be equal, consequently the boiler seams would probably leak and the boiler be injured.

Q. What benefit is gained by letting water stay in the boiler until you are ready to clean out?

A. The mud is kept soft and the scale is not caked to the bottom, also the seams

and boiler are not injured by unequal expansion and contraction.

Q. How should a man-head and hand-hole head be taken out and put in?

A. They should be marked with a chisel at the top, also the boiler at man-hole and hand-hole, which ever it might be and they should be put in the same way they came out.

Q. How would you gasket man-hole or hand-hole heads?

A. With pure lead rings; some use sheet rubber.

Q. Why are man-hole and hand-hole heads made oblong instead of round?

A Because if they were round, they could not be taken out and a man could not enter the boiler.

Q. When filling a boiler with cold water and raising steam, what should be done?—A. A valve should be left open.

Q. Why?—A. Because a boiler fills easier and quicker, and in raising steam the cold air is let out, which allows equal expansion, as cold air will not allow equal expansion.

Q. How would you set a boiler?

A. By using a spirit level across the flues, and along the flues, and allow the end furthest from the gauge cocks ½ in. lower for every 10 feet.

Q. Why?—A. Because when there is water in the gauge cocks, there will surely be water in the other end.

Q. How many gauge cocks has a boiler?

A. Generally three.

Q. Where is the first?

A. Two inches above the flues and the rest 2 in. apart.

Q. Where is the water line?

A. Second gauge.

Q. Where would you carry water when running?—A. Second gauge.

Q. Where would you carry water when shutting down at night?—A. Third gauge.

Q. Why?—A. To allow for evaporation, leakage and condensation.

Q. Where is the fire line of a boiler?

A. Two-thirds the circumference.

Q. When you open a boiler and look in, where do the scales lay thickest?

A. Over the fire plates and around the

mud-drum leg or blow-off pipe. Q. Why?

A. Because the circulation and heat is greatest there.

Q. What is a steam drum for?

A. To have more volume and dryer steam.

Q. Which is the hottest, steam or water?

A. They are the same, only water will retain the heat longer, as water is a body and steam a vapor. The circulation and feed should be continual if possible.

Q. Why?—A. Because boilers have exploded just as the steam valve was opened to start the engine, after having stood still for some time. This is generally caused by the plates that are in contact with the fire becoming overheated, as the circulation being stopped after the steam is shut off. And just as soon as the valve is opened the pressure becomes lessened, and the water on the overheated sheets flash into steam of GREAT ELASTIC FORCE, and if the boiler is not strong enough, an explosion is the result.

Q. If you tried the gauge cocks, and found no water in sight, what would you do?

A. Simply put wet ashes over the fire and pull it out, raise flue caps and let the boiler cool down.

Q. Why do you throw wet ashes over the fire before pulling it out?

A. If the fire was stirred up it would create more heat and be liable to burn the plates.

The braces in the boiler shold be examined to see if they are loose, also the sheets, flues, heads and seams, to see if they are cracked or leaking; if they are not attended to, they may cause trouble and loss of life and limb. Engineers should not allow anything about the engine or boiler room to become greasy or dirty, for it shows poor management, a careless and worthless engineer. If valves or cocks leak, they should be ground in with Emery and Oil until a seat or true bearing is found.

Q. When should the boiler seams be corked?

A. When the boiler is empty and cold, for when the boiler is hot and filled with water, the jarring while corking would have a tendency to spring a leak somewhere else.

Q. Would you call pressure and weight the same? A. No.

Q. Why?—A. Because pressure forces in every direction, while weight presses down.

Q. Which is best, riveted or rolled flues?

A. Rolled flues, as they are a true circle and not so easily collapsed as riveted flues. Q. Why?

A. Because the riveted flues are not a true circle.

Q. What is foaming?

A. Foaming is water and steam mixed together.

Q. What causes foaming?

A. Dirty, greasy, oily and soapy water, also salt water forced into fresh water will cause foaming.

Q. What is priming?

A. Priming is the lifting of water with steam, such as opening a valve suddenly, and drawing water from the boiler to the cylinder of the engine.

Q. What would you do in that case?

A. Close the throttle valve and leave it

closed for a few minutes, then open slowly, that will remedy it. Sometimes priming is caused by too much water in the boiler, and not enough steam room, in this case carry a little less water.

Q. Are boilers sometimes injured by hydraulic test?

A. Yes, if tested by an inexperienced person. Hydraulic test is the safest, because if the boiler is bursted no one is likely to get hurt.

Q. If you had a high pressure of steam, and water was out of sight, would you raise the safety valve to let off pressure?

A. No. Q. Why?

A. Because it would cause the water to rise, and when the valve closed the water would drop on the heated parts and be liable to cause an explosion.

Q. What kind of a steam gauge have you got? A. A spring gauge.

Q. What is a steam gauge for?

A. To indicate the pressure in pounds per square inch in the boiler.

Q. Does the steam gauge get out of order? A. Yes.

Q. If the steam gauge was out of order what would you be governed by ?

A. By the safety valve.

Q. How would you know that it was in order ?

A. By raising the lever two or three times to see that the valve is not stuck.

Q. What is a safety valve for ?

A. It is intended to release the boiler from overpressure and prevent explosions.

Q. Is there any other way to tell, if you had no steam gauge ?

A. Yes, by the thermometer.

Q. How would you do that ?

A. By taking a large mouthed bottle, or anything else that will hold the thermometer, then hold it under a valve or gauge cock near the boiler, and let steam pass over it and it will indicate pressure ; if it shows 212° it is 15 lbs. pressure, if 228° it is 20 lbs., if 269° it is 40 lbs., if 295° it is 60 lbs. etc.

Q. If your boiler was too small to keep up the amount of steam required, would you weigh down the safety valve to carry a higher pressure ? A. No.

Q. Why? A. Because that would show carelessness, and a violation of the laws.

NOTE.—Engineers should know that a counter-sunk rivet is not as good as a flush-head of the same diameter and space apart because it has not the same strength.

PUMPS.

Q. What kind of pumps are there?

A. There are many kinds, but we consider only single action and double action for feeding boilers.

Q. How many valves has a single action plunger pump?

A. Two valves, a receiving and a discharge.

Q. How many valves has a double action?

A. Four, two receiving and two discharging. The double action receives and discharges both ways. This kind of pump has a steam cylinder on one end.

Q. How would you set up and level a pump?

A. Set the pump so the receiving is from the boiler and the discharge towards the boiler, put in the same size receiving and discharge pipe as tapped in the pump,

so the pump can have a good supply, and a regular discharge. The pump is leveled with a spirit level or a square and plumb line. To level a double action pump, some level across the frame and along the piston; the other way is to take the valve chamber cap off of the water cylinder, and level the valve seats, so the valves will raise and drop plumb. To level a single action pump, take off the valve chamber caps and level both ways.

Q. How is the water piston packed and with what?

A. It is generally packed with square canvass and rubber mixed packing, it generally takes two pieces, one piece is jointed on top, and the other on the bottom to make what engineers call a broken joint. The packing runs from ¼ to ⅞ in. square. These are the general sizes used for common sized pumps.

Q. What other valve has a pump near the boiler?

A. A check valve.

Q. What is a check valve for?

A. To check the pressure, and keep the

water in the boiler from coming back, in case there is any work to be done on the pump.

Q. Could you pump water into the boiler, if you had 4 or 5 check valves on the discharge pipe?

A. Yes, I could force through all, but it would be more labor on the pump, because the plunger would have to force harder to raise the number of check valves.

Q. Where is a pet cock put on pump barrel and what for?

A. It is put at the side and near the bottom of pump barrel, and is there to show how the pump is working, and to drain pump barrel in winter to keep from freezing.

Q. How do you know when your pump is in good working order?

A. By opening pet cock and seeing the stream that comes out.

Q. How does it show when in good working order?

A. Nothing on the up stroke and full force on the down stroke.

Q. Where would you locate the trouble

if it came full force both ways?

A. I would locate it at check and discharge valves both being caught up.

Q. Where would you locate the trouble if it came full force, moderate, tank or hydrant pressure?

A. At receiving valve.

Q. Can you run a pump without a check valve?

A. If my discharge valve is in good order I can, but if I have neither check or discharge, I cannot.

Q. Can you feed a boiler without a pump at all?

A. If the pressure of boiler is below the pressure of the feed water or city pressure, I can, by simply opening a valve and letting in the amount of water needed.

Q. What other ways is a boiler fed?

A. By an injector and inspirator.

Q. Must a pump have a valve?

A. Yes, if a pump had no valve it would not do any work.

A pump is not a pump unless it has a valve. There are common well hand pumps with one valve, called a receiving or suction

valve, but a force pump has two valves, a receiving and discharge, the discharge is to retain the water after it is delivered, so the plunger can get a fresh supply. After the plunger has ascended and begins to decend the water sets on top of the receiving and under the discharge, consequently when the plunger decends it forces the receiving shut and the discharge open.

Q. Should there not be another valve near the boiler?

A. Yes, a globe valve between the check valve and boiler.

Q. What is that for?

A. To close and keep pressure in the boiler in case the check valve is caught up and needs repairing.

Q. Can you raise, lift or suck hot water with a pump?

A. Not very well. Q. Why?

A. Because the pump would get steam bound. Hot water should be level or higher than the pump to have pump working well.

Q. Where should a pet cock be put on pump barrel for hot water?

A. At the top of barrel, immediately under the packing ring.

Q. Why is it put there?

A. To let out steam when steam bound and air when air bound. There should be a pet cock on each cap of valve box to let off steam or air when steam or air bound.

Q. If you had no pet cock on valve boxes what would you do?

A. I would take a wrench and loosen one of the nuts a little until the air or steam was out, then tighten again.

Q. Why is an air chamber put on a double action pump?

A. It is simply a copper vessel air tight. When the pump is working, the water goes up into the chamber, compresses the air and the air acts as a cushion on the valves and piston head in the water cylinder.

Q. What is a cushion?

A. A cushion is anything that is compressed, and by its compression is formed into a higher and stronger pressure, consequently acting as a spring, deadening any knock that might have occurred otherwise, as water will cause a knock, it being

nearly as solid as iron, so if a double action pump had no air chamber, there would be a continued thumping noise.

Q. What is a vacuum?

A. A vacuum is an empty space containing nothing.

Q. Can a perfect vacuum be formed?

A. No about 11 to 13 per cent of the atmosphere, which is 14.7 lbs. per square inch.

Q. What will a vacuum do?

A. It will lift water 33 feet, providing all pipes and connections are air tight.

Q. How is a vacuum created or made?

A. When the plunger of a pump is well packed and it lifts, it excludes the air out of the pump barrel and suction pipe, consequently the water being at the other end of pipe it follows the plunger; or in other words, the atmospheric pressure being 14.7 lbs. per square inch, forces the water up the pipe to fill the vacancy made by plunger forming the vacuum.

Q. What should be placed at the bottom of the suction pipe?

A. A strainer made out of gauze wire,

a foot valve and a pet cock to drain it.

Q. If your pump should not be working, your water running low and you was asked to run a little while longer, would you run and let your water become dangerously low?

A. No, take no chances whatever, but shut down and go about repairing the trouble.

Q. Where would you look for the trouble?

A. Open pet cock of the pump and that would very nearly tell where to look for it, if no water came out, the water is shut off or there is none.

Q. What generally prevents a pump from working?

A. Not enough water, too small a suction pipe and obstructions of the valves to seat, by straws, sticks or anything that may be drawn through the suction pipe, or the pump valves becoming hot and sticking.

Q. If an accident happened, such as a broken pipe connected with the boiler and pump, or you could not get sufficient water to supply the boiler, what would you do?

A. Simply shut down the engine, and all valves connected with the boiler, draw fire, raise flue caps, and close the damper so as to keep water in the boiler, until the difficulty is repaired.

Q. If your suction pipe should spring a leak what would you do?

A. Take a piece of sheet rubber, some copper wire, wrap around tight and stop the leak temporarily.

Q. If your hydrant, that supplies pump with water, should happen to get broken, what would you do?

A. First see how much water was in the boiler, by trying gauge-cocks, then shut off in the street or wherever the lazy cocks lay and try to wrap it, if possible, or repair it. If an injector or inspirator was attached, and was supplied from a tank or well, use them.

Q. For instance, if you had neither of these, what would you do?

A. Shut down the engine, close the damper, raise the flue caps and draw fire, whichever suited the circumstances.

Q. If your pump was turned around,

could you feed the boiler? A. No.

Q. What would be the consequence?

A. If the packing in the pump held out, the plunger would exclude the air and collapse the discharge pipe.

Q. Would it not have a tendency to drain the water out of the boiler?

A. No, the check valve near the boiler would keep it back.

Q. If you had no check valve what would it do?

A. The water would run out, that is, providing the pump was turned around.

Q. If the pump plunger is ½ the stroke of the engine, what should the diameter be?

A. ⅓ the diameter of engine cylinder.

Q. How high should a valve lift to clear itself?

A. About ¼ its diameter or ⅓ its area.

Q. What proportions should the valves be to any sized pump?

A. They shoud be ¼ the area of the pump.

Q. Where would you put a steam gauge?

A. Sometimes on top of the boiler, and in some cases on the steam drum. It must

always be tapped into the steam part of the boiler, the shorter the pipe the better. The steam gauge and safety valve should correspond.

Q. What is a pet-cock put under the steam gauge for?

A. To drain the pipe in cold weather and let out condensed water.

Q. How often would you do that?

A. Whenever it accumulated, about two or three times a day in winter.

Q. What is the best, gauge-cocks or glass gauges, and what would you be governed by?

A. Gauge-cocks, because glass gauges are liable to get stopped with mud, and not give a true level of the water, but they are a very handy thing; they should be blown out 4 or 5 times a day, so as to keep them free from clogging up.

Q. What would you do in case a glass should happen to break?

A. First close the water valve to prevent the escape of water, close the steam valve, insert a new glass, then turn on the steam valve first, then the water valve,

then close the pet-cock at the bottom and everything will be all right.

Q. What is an Injector or Inspirator?

A. They are a device to answer for a pump in feeding a boiler; they draw, force and heat the water at the same time?

Q. If your gauge-cock or a small pipe in the large steam pipe should happen to get broken off, what would you do?

A. Make a hard wood plug and drive it in with a heavy hammer, then leave it so until it could be repaired, by cutting out the old piece, retapping and putting in another pipe or gauge-cock, whichever the case might be.

Q. If water should accumulate in the cylinder, what would be the consequence?

A. It is liable to crack the cylinder and disable the engine.

Q. If you have charge of a engine in the country, and the cylinder head should happen to break,how would you remedy it?

A. If not broken too bad, try to patch it with pieces of iron or boards, and brace it from the wall with a piece of heavy piece of scantling, then try and run until

a new cylinder head could be made.

Q. What size should a steam pipe and an exhaust pipe be?

A. The steam pipe should be ¼ and the exhaust ⅓ the diameter of the cylinder.

Q. If your crank pin or other journals get hot, what would you do?

A. Try, while running, to get water on them, then oil them; if that would not do, stop and slack up the key a little, then start up again.

All engine cylinders should be well drained and heated before starting, then the engine should be started slowly, as the water that accumulates in the cylinder may injure the piston, cylinder or cylinder heads. Always leave the cylinder-cocks open when not running, and they should remain so until the engine is heated by the steam, after the engine has been running at full speed 2 or 3 minutes.

Q. If the cylinder had shoulders inside, and was out of a true circle, what would you do?

A. Bore it or have it bored out.

Q. If your slide-valve was not steam

tight, what would you do?

A. Have the valve planed, then chip, file and scrape the seat to a full bearing.

Q. If the crank and wrist pins are worn out of true, what would you do?

A. Calliper and file them, until they were round and true.

Q What causes the wrist in the cross-head and crank-pin to wear the way they do?

A. It is simply the motion they have; the crank goes all the way around and the wrist only vibrates.

Q. If the cross-head or crank-pin brasses were brass bound, what should be done?

A. They should be chipped and filed.

Q. How do you know when you have taken enough off?

A. By inside and outside callipers.

Q. How does steam enter the cylinder?

A. In common slide valve engines, it enters through one of the end ports and exhausts back through the same port, when the cavity of the valve has covered it and the exhaust port at the same time.

Q. What is a cavity?

A. It is a hollow space in the valve itself, where the exhaust passes through to the atmosphere.

On Corliss' engines and other makes, there are other valves, called exhaust valves; a Corliss' has two steam and two exhaust.

Q. Where are they?

A. The two steam valves are on top at each end of the cylinder, and the exhausts are at the two bottom ends.

Q. What are the advantages of common slide valve engines over other makes?

A. They are cheaper when first bought, more positive in their action, and simpler in their designs.

Q. What throw should a common slide valve engine eccentric have?

A. Generally double the width of the entry or steam ports.

Q. What is meant by the lead of valve?

A. The opening the valve has when the piston is at the beginning of its stroke.

Q. What lead should large engines have?

A. About $\frac{1}{16}$ inch. High speed engines must have a quick opening or good lead.

THE ENGINE.

Q. What is an engine composed of?

A A bed plate, cylinder, connecting-rod, crank, crank-shaft, main pillow block, tail pillow block, cross-head, wrist-pin in cross-head, crank-pin, two cylinder-heads, piston-rod, piston-head, follower-head, bull-ring, packing rings, follower-bolts, connecting rod brasses, pillow-block-brasses and guides where the cross-head slides in so the piston is kept central with the cylinder. The main pillow-block brasses are generally made into four pieces, called top and bottom brasses and two quarter brasses each side of shaft; they are made into four parts so as to take up lost motion.

Q. What keeps the rod from running off the crank-pin?

A. The shoulders on crank-pin.

Q. Why are the stub ends of straps

made heavier where gib and key passes through?

A. To make up for the amount of iron taken out for gib and key-way.

Q. If the throttle valve broke, and you could not stop the engine with throttle, how would you stop it?

A. I would lift eccentric rod off of rocker arm pin, and move valve by hand with a starting bar, until valve covers both ports equally, then the engine will come to a stop.

Q. What is meant by a cushion in an engine cylinder?

A. Cushion is the resistance on the opposite side of piston-head, formed by the steam being shut up in the cylinder, as the piston is moving toward either dead centre.

Q. What is meant by clearance?

A. Clearance is the space between the piston head, cylinder head and valve face at each end of the stroke.

Q. How would you know the amount of clearance there was in that space?

A. By finding the number of cubic inches in a bucket of water, then fill up the space level with the steam port, then see

how much water is left in the bucket, the difference is the contents in cubic inches.

Q. Why are gibs, keys and set screws used on both ends of connecting rod?

A. They are there to take up lost motion.

Q. How would you do that?

A. By loosening up the set screw, and driving down the key, then tighten the set screw to keep the key from raising.

Q. Is there more square inches in one end of the cylinder than in the other?

A. In one sense of the word there are and in the other there are not, as the piston rod takes up some of the space in one end of the cylinder, therefor there is not the same area in one end as in the other.

Q. What is a governor on an engine for?

A. It is to regulate the steam that passes from the boiler to the steam chest, when the throttle is wide open.

Q. How does it work?

A. It is regulated to allow the engine to run at a certain speed, the governor has a belt from the main shaft to a pulley on the governor, after the engine is running up to the speed it is intended to, it allows only

enough steam to enter through the governor valve to keep the same speed; if the engine needs more power it begins to slack up, the governor balls drop and the valve opens and allows more steam to enter; consequently the engine must retain her speed, and if the load is taken off it will start to run away, and the governor balls will raise up, force the valve shut, and shut off the steam, consequently the engine must come back to its regular speed.

Q. How does a governor valve look?

A. It is a round valve with grooves, some are made different from others, some have three or four openings, some have only two; the more openings the more sensitive the governor.

Q. What is a lubricator for?

A. It is to saturate the steam that passes through the governor valve and the engine valve with oil, so they will not cut; the piston packing rings and the cylinder is also oiled by the same steam and oil.

LINING AN ENGINE.

Q. How would you line up an engine?

A. By stripping the engine, take off both cylinder heads if convenient, then take out the follower-head, piston-rings, bull-ring, disconnect the piston from cross-head, also disconnect the connecting-rod from the cross-head and crank-pin, then take a slotted stick and place it on one of the studs on the end of cylinder furthest from the crank, then draw a fine sea-grass line over the point of stick and through the centre of cylinder, and attach it to a stick at the other end of the bed-plate, nailed to the floor or clamped to the bed-plate, then take a thin stick, the length of it being a half inch less than half the diameter of cylinder, and stick a pin in each end of the stick, so they can be forced in or drawn out to suit the adjustment, then centre the

line at each end of the cylinder at the counter-bore from four sides. Never centre the line in the stuffing box where the piston passes through, but use the inside counter-bore under all circumstances, whether you can remove the back cylinder-head or not. Some engine cylinder heads and frame are one, consequently the head cannot and must not be moved.

Q. If one counter-bore would be out, or larger than the other, what would you do, would it not throw the bore of the cylinder or the line out?

A. No, centre it accordingly; but it would not make any difference, only two centering sticks with pins are needed to bring the line central with the bore.

Q. Why do you use the counter-bore?

A, Because the counter-bore is the only true bore the cylinder has that is not worn, consequently all engineers must go by it.

Q. What is a counter-bore for?

A. To keep the piston from wearing a shoulder in the cylinder at each end.

Q. What is a counter-bore?

A. A counter-bore is each end of the

cylinder bored $\frac{1}{16}$ to $\frac{1}{8}$ inches larger, from 1 to 4 inches long according to size and length of cylinder.

Q. Why is it that the piston does not wear a shoulder in the cylinder?

A. Because the piston rings just pass over the edge of the regular bore, and by so doing, no shoulder can be formed in the cylinder.

Q. How is a cylinder bored?

A. They are generally bored on a regular cylinder boring lathe, which has a table that can be raised or lowered to suit, The regular bore is first bored, then the counter-bore, then the two faces for the heads.

Q. How do you square a shaft when you have got the line centrally through the cylinder?

A. First find the centre between the two shoulders of the crank pin, and move the crank-pin down to the line and see how it comes, then move it over to the other dead centre and see how it comes, if equal, the shaft is square.

Q. If you found it out of square ½ inch

what would you do? A. Move tail block.

Q. Why not move the head-block?

A. Because it would alter the length of the connecting-rod and liable to knock out a cylinder-head.

Q. How would you level a shaft?

A. A shaft is leveled by a spirit level, or a plumb bob line dropped past close to the line that comes through the cylinder directly in front of the centre of shaft, let it drop in a bucket of water to keep the plumb from swaying around, then try the crank-pin at both half strokes, top and bottom, and see how the crank pin feels the line, if equal the shaft is level.

Q. If you found the shaft out of level, what would you do?

A. I would have to thin or thicken the brasses or babbitt the main pillow and tail block bearings whichever the case may be.

Q. How would you know if the centre of the shaft is in line with line through the cylinder or not?

A. It can be found out by placing a 2 ft. steel square against the crank face so that the heel of the square is at the centre

of the shaft, and see how the square touches the line, if it touches exactly, the shaft is in line; if too hard, the shaft is too high; if not at all, the shaft is too low.

Q. How would you raise your shaft?

A. There are various ways; by liners, babbitt, heavier or lighter brasses.

Q. If your crank face was oval, and you put a square against it, would that be right?

A. A spirit level could be placed on a square and bring it level, or drop a plumb-line, and put the end of the square against the crank-shaft centre and let it come against the plumb-line. This is a very true way.

Q. Now, after your shaft is in line, square and level, and you still find it out over line ¼ inch, what would you do?

A. I would take it off of the crank-pin brasses and fill in the other side with a brass ring, or babbitt the side edge of brasses, in some cases the side of the connecting rod has to be chipped to allow it to pass free of the crank face.

Q. Why would you not take it off of the wrist-pin brasses in the cross-head?

A. Because the rod would be out of the centre of cross-head, and it would have a tendency to bind the piston in the cylinder and the cross-head on the guides, consequently cutting both.

Q. Would it not make a difference on the other end of the rod?

A. No, the closer the crank-face the better.

Q. Now what do you do?

A. Level and line the guides by putting them in their place; and line them with a pair of callipers, by callipering them at both ends to get them in line, with the line through the cylinder, after having found the distance between the side of the cross-head and the centre of the cross-head where the piston enters the cross-head. Level by spirit level, first taking spirit level and trying it in the cylinder, if a new one, or on top of the cylinder where it has been planed off when first bored, for they are the only things to go by.

Q. Would you use the valve seat?

A. No, but along side of it, where the steam chest sets on.

Q. If you had no spirit level, how would you do it?

A. With a plumb-line, by placing a square lengthwise on the guides and try them by bringing the square against the line.

Q. Can a plumb-line hang out of true?

A. It cannot, providing, it hangs clear of everything; if none of these were handy, a straight edge must be placed across the guides at one end, and see if the guides touch the straight edge equally both edges, then calliper the distance between the line and the straight-edge, also at the other end of the guides, if the same, the guides are level lengthwise with the cylinder and line; then level the guides crosswise with a plumb-line and square.

Q. How would you measure your connecting rod?

A. By finding the striking points.

Q. How would you do that?

A. By shoving the piston and cross-head up against the cylinder-head, and making a mark on the guides at one end of the cross-head, with a scriber and centre-

punch, then move the piston and cross-head back to the other cylinder-head and make another mark on the guide, at the same end of the cross-head; then measure from the centre of crank-pin to centre of shaft, that gives the half stroke; double this, gives full stroke. If half stroke is 12 in., the full stroke is 24 in., then if the distance between the two striking points is 25 in. and the stroke 24 in., the clearance between the cylinder-head and piston-head will be ½ in. when the piston is at either end of the cylinder. Then move the cross-head ½ in. back from the striking point, and bring the crank-pin toward the same dead centre, then take a tram and measure from outside centre of crank-pin to the outside centre of wrist-pin in cross-head, which will give proper length of connecting-rod, also the right division of clearance.

Q. What is meant by clearance in the cylinder?

A. It is the unoccupied space between the piston-head, cylinder-head and valve-face, when the crank is at the dead centre.

Q. Does the amount of clearance effect

the engines economy? A. Yes it does.

Q. How much clearance should there be between the piston and cylinder-head?

A. It depents upon the size; some have from ¼ to ⅞ inches.

Q. What is formed in that space or clearance when running? A. A cushion.

Q. What is a cushion?

A. A cushion means the steam that enters the cylinder through the lead the valve has, and the resistance it makes on the piston-head, cylinder-head and valve-face, as the engine is reaching the dead centre.

Q. What is a cushion for?

A. It is to catch the piston and weight of the machinery as it reaches the dead centre, and the lead is to give the engine power at the beginning of the stroke.

Q. How does it act?

A. The same as a spring on the end of a hammer.

Q. If you wanted to shorten or lengthen the connecting-rod, how could it be done?

A. By placing tin or sheet-iron liners between the brasses and stub ends of the connecting-rod.

Q. Now if the key had to be raised, how could that be done?

A. By putting liners between the straps and brasses.

Q. Would that not alter the length of the rod? A. No.

Q. With what instrument would you measure a connecting-rod?

A. It is called a "tram."

Q. How is an engine packed in the stuffing box?

A. Some engineers use hemp, others use black lead packing, and others use lead rings; there are several different ways. Every engineer to his own taste.

VALVE MOTION.

Q. What is an eccentric?

A. An eccentric is a subterfuge for a crank, it is something out of centre.

Q. How would you find the throw or stroke of an eccentric?

A. By measuring the heavy and the light side, the difference between the two is the stroke or throw.

Q. What is a cam?

A. A cam has no definite meaning, it has 1-2-3 or 4 motions, they are used on poppet valve engines, such as are in use on high pressure river boats.

Q. How would you measure your valve and eccentric rods?

A. By placing the crank-pin at its dead centre, the centre of the eccentric straight or plumb above the centre of the shaft, the rocker-arm perpendicular, and the valve

covering both ports equally, then take a tram and measure from the centre of the eccentric to the centre of the pin where the eccentric rod hooks on (generally the lower pin) for the eccentric-rod, and from the outside centre of the pin where the valve-rod is attached to the furthermost end of the valve, allowing for two nuts at each end of the valve, called adjusting and jamb nuts.

An eccentric-rod consists of a strap, yoke, rod and two nuts; when taking the measure, couple the yoke and strap together, then put a ½ in. thick piece of wood between the two straps and find the centre of the circle from four sides, with a pair of hermaphrodite callipers, then put the rod in the yoke and adjust it to the proper length by the two nuts, if that will not do, the rod must be shortened or lengthened, by cutting out or adding a piece, whichever the case may be. Then take the measure with a tram from the centre of straps to the centre of the rod where the rod hooks on the lower rocker-arm pin.

Q. How long is the thread on a valve-rod?

A. Long enough to allow two nuts at each end of the valve, and some space for adjustment.

Q. Now if your rocker-arm stood at a quarter, and your eccentric out of plumb, how would you take the measure for the rods?

A. Simply bring them plumb and take the measure, that is the only right way.

Q. After you have measured your rods what would you do?

A. They should be put on, and the valve set?

Q. What do you move or do first, to set a valve?

A. Move the eccentric in the direction the engine is to run, until the valve begins to take steam or lead, then tighten the eccentric temporaily with set screws, then move the crank over to the other dead centre, and see how much lead it has, if equal, the valve is set.

Q. Now if you find it out ⅜ of an inch on one end, and the proper lead on the other, what would you do?

A. Divide the difference, by moving the

valve one-half it is out, by adjusting the nuts on the valve gear, which will make $\frac{3}{16}$ of an inch, then move the eccentric to get the lead again, then move the crank on the other dead centre, and the valve will in all probabilities be set.

Q. But if it does not, what then?

A. Go through the same performance until it is set. Some valve-rods have a yoke that slips over the valve, while the adjusting and jam-nuts are between the stuffing box and the rocker-arm pin. When a valve-rod has no nuts, the adjusting must be done at the eccentric-rod, or raise or lower the eccentic-rod pin in the slott, at the bottom of the rocker-arm.

Q. Now after you have set your valve, keyed everything up properly, and there was a thud or dead sound in the engine or cylinder, what would you do, or where would you look for the trouble?

A. In the exhaust being choked. The steam-chest cover must be taken off, then uncouple the valve, turn the valve up sideways and move it until the steam edge has the proper lead with the steam-port, then

a square must be placed on the valve-seat of the cylinder, and against the valve-face to see how the exhaust lead on the opposite steam port corresponds; if it is choked, then scribe it by allowing a little over double the steam lead.

Q. How would you make the exhaust larger?

A. By chipping it out of the exhaust cavity in the valve, and rub a file over it to smooth it.

Q. Do you think a little over double the steam-lead would be sufficient?

A. Yes, if not, take out a little more.

Q. Where should that exhaust be?

A. It should be the furthest from the steam-port, that is receiving.

Q. How would you find the dead centre of an engine?

A. By placing a spirit level on the strap that goes around the brasses, that connect the crank-pin to the connecting-rod, and when it is level, the crank is at dead centre.

Q. What would you do in case your eccentric slipped?

A. Set the valve the same as before.

Q. Is the principal of valve setting the same?

A. Yes, some engines have two steam and two exhaust valves, but that makes no difference.

Q. What other way could you find the dead centre of an engine?

A. By moving the engine toward the dead centre, until the cross-head stopped moving, then put a centre punch mark in the floor, and one on the fly-wheel, after having marked it with a tram, then move the crank over the centre, until the cross-head begins to move, then put another mark in the middle, between the two marks this is the exact dead centre; then bring the middle mark to the point of the tram; this is done with a small tram, with one straight point and an L.

Q. If the engine had to be run in the opposite direction to which it had been running how could it be done?

A. It could be done by placing the crank-pin on the dead centre, removing the steam-chest cover, and turning the eccentric around on the shaft in the opposite

direction, until the valve has the proper lead, then try the engine from the dead centre to dead centre, to equalize the lead at both ends of the valve, then the engine will run in the opposite direction.

Q. Does a crank-pin and piston travel the same?

A. No, a crank-pin travels six times as far, while the piston is moving the first inch of its stroke, as while it (piston) makes the middle inch; a little over twice as far, while the piston travels the second inch; a little more than one and one-half times as far, while the piston is making the third inch; and less than one and one-half times as far, while the piston is making its 4th inch. The crank travels less when the piston is making the last inch of the stroke than it does when making the first inch. Another fact not generally recognized by inexperienced men, is that a crank of an engine at certain points travels a long way, while the cross-head has a motion that is hardly noticed.

When the centre of the crank-shaft and crank-pin are in line with the piston-rod,

no pressure applied to either side of the piston, can set the engine in motion; this is called the dead centre.

Q. If you were asked the horse power of any sized engine could you tell it?

A. Yes.

Q. Well, how would you go about it, and what is a horse power?

A. A horse power is 33,000 lbs. raised 1 ft. high in 1 minute, or 150 lbs. raised 220 ft. high in 1 minute. To find the horse power of any engine, first find the area of the piston-head, then multiply the answer by the average pounds pressure per square inch, then multiply by the number of feet traveled in 1 minute, and divide by 33,000. If you calculate from boiler pressure, you must allow about .13 per cent for loss by friction; but if you take pressure off of the indicator card, you need not take off .13 per cent, as the indicator will indicate average pressure per square inch on the diagram.

THE INDICATOR.

The steam engine indicator, is an instrument for showing the pressure of steam in the cylinder, at all points of the stroke, or for producing actual diagrams. The indicator consists of a small cylinder accurately bored out, and fitted with a piston, capable of working in the (indicator) cylinder with little or no friction, and yet be practically steam-tight. The piston has an area of just ½ of a square inch, and its motion in the cylinder is $\frac{25}{32}$ of an inch.

The piston-rod is connected to a pair of light levers, so linked together, that a pencil carried at the centre of the link, moves in nearly a straight line through a maximum distance of 3⅛ inches. A spiral spring placed in the cylinder above the piston, and of a strength proportioned to the steam pressure, resists the motion of the piston; and the elasticity of this spring is such, that each pound of pressure on

the piston, causes the pencil to move a certain fractional part of an inch. The pencil in this case is made of a piece of pointed brass wire, which retains its sharpness for a considerable time, and yet makes a well defined line upon the prepared paper generally used with the indicator.

The paper is wound around the drum, which has a diameter of 2 inches, and is capable of a semi-rotary motion upon its axis to such an extent, that the extreme length of diagram may be 5¼ inches. Motion is given to the drum in one direction, during the forward stroke of the engine, by means of a cord, connected indirectly to the cross-head of the engine, and the drum is brought back again during the return stroke of the engine, by the action of a coiled spring at its base.

The conical stem of the instrument, permits it to be turned around and fixed in any desired position, and the guide-pulleys attached to the instrument under the paper drum, may also be moved around so as to bring the cord upon the drum-pulley from any convenient direction.

The upper side of the piston is open to the atmosphere, the lower side may, by means of a stop-cock, be put into comunication either with the atmosphere or with the engine cylinder.

When both sides of the piston are pressed upon by the atmosphere, the pencil, on being brought into contact with the moving paper, describes the atmospheric line. When the lower side of the piston is in communication with the engine cylinder, the position of the pencil, is determined by the pressure of the steam existing in the cylinder; and on the pencil being pressed against the paper, during a complete double stroke of the engine, the entire indicator diagram is described.

In order that the diagram shall be correct, the motion of the drum and paper shall coincide exactly with that of the engine piston; second, that the position of the pencil shall precisely indicate the pressure of steam in the cylinder; third that the pendulum must be from 1½ to 3 times as long as the stroke of the engine piston; fourth, that the pendulum must be

plumb, when the piston is at half stroke; fifth, that the cord around the drum must be attached to the pendalum at right angles or square with the indicator; sixth, the pendulum must be attached with and inch wooden pin to the ceiling or floor at one end, the other end to the cross-head by means of a screw-bolt and a slot in the pendulum; seventh, that the two holes tapped in the cylinder, are directly opposite the steam ports, and centrally between the piston-head and cylinder-head, when the engine is at the dead centre, or in other words, in the centre of clearance; eighth, that the piping should be as short as possible, and ½ inch pipe if not over 1 ft. long. If longer the pipe should be larger, close to the cylinder and covered, so as not to allow too much condensation, as it effects the diagram. The best way to take a diagram, is to tap a hole in each cylinder-head and take each end separately. The cord must be attached to the pendulum, so the paper drum will move in proportion to the piston.

An indicator shows the highest and the lowest pressure reached, also the cut-off and lead. If there is a great difference, say more than 5 lbs. between the boiler pressure and the initial pressure upon the piston, the connecting pipes may be taken as being too small, too abrupt or the steam ports too contracted. The full pressure of steam should come upon the piston at the very beginning of its stroke. Should the admission corner be rounded, the valve is wanting in "lead," or in other words, the port for the admission of steam is uncovered too late in the stroke.

The steam line should be parallel or straight with the atmospheric line, up to the point of cut-off, or nearly so. Should it (the steam line) fall as the piston advances, the opening for the admission of steam is insufficient,and the steam is"wiredrawn."

The point of cut-off should be sharp and well defined; should it be otherwise, the valve does not close quick enough. The bevel line leading from the cut-off line to the end of the stroke, is called the expansion line;

Q. What is the standard indicator?

A. The Thompson improved.

Q. Are there any other makes?

A. Yes, Richard's, McNought's, Tabor's and others.

Q. If you had no 2 ft. square and could not get any, how would you lay one off?

A. Take a pair of dividers and draw a circle, then find four points on the circle, and scribe lines from point to point, which will give you a square. This should be done very acurately.

How to mark engineer's tools. Warm the tool and allow a thin coat of beeswax to cover the place to be marked; after the beeswax is cold, take a dull scriber and do the marking; then apply some nitric acid, after a few moments wash off the acid with water, then heat the tool to melt the beeswax.

How to reduce decimals to fractional parts of an inch.

$\frac{1}{16}$ ..... .0625	$\frac{3}{8}$ ..... .375	$\frac{11}{16}$ ..... .6875
$\frac{1}{8}$ ..... .125	$\frac{7}{16}$ ..... .4375	$\frac{3}{4}$ ..... .75
$\frac{3}{16}$ ..... .1875	$\frac{1}{2}$ 5	$\frac{13}{16}$ ..... .8125
$\frac{1}{4}$ ..... .25	$\frac{9}{16}$ ..... .5625	$\frac{7}{8}$ ..... .875
$\frac{5}{16}$ ..... .3125	$\frac{5}{8}$ ..... .625	$\frac{15}{16}$ ..... .9375

RULES.

Here are several rules that should be continually in an engineer's mind.

RULE for telling the power of a diagram. Set down the length of the spaces formed by the vertical lines from the base in measurements of a scale, accompanying the indicator, and on which a tenth of an inch usually represents a pound of pressure, add up the total length of all the spaces, which will give the main length or the mean pressure upon the piston in lbs. per square inch; to do this, lay a card taken by the indicator off in ten parts, by drawing lines from top to bottom. Find out what the scale is, suppose it is 60, the number of ordinates 10 and that the sum of their length is 6 inches, so 6 and 10 ordinates $= \frac{6}{10}$ or $.6 \times 60 = 36.0$ Answer 36 lbs. pressure upon the piston.

RULE for finding and deducting friction. Multiply N. H. P. by .13 and subtract the answer from N. H. P., which gives I. H. P.

Q. What is N. H. P.?

A. It is nominal horse power.

Q. What is I. H. P.?

A. It is indicated horse power.

Q. What is a revolution?

A. It means the crank has turned once around.

Q. How many strokes has a revolution?

A. Two.

EXAMPLE:—If an engine has 24 inch stroke, and makes 65 revolutions per minute, how many feet does it travel in a minute? 24 in. x 2 = 48 in. x 65 rev. = 3120 in. ÷ 12 =260 ft. per minute.

Q. What is meant by cutting off steam at 6 inches?

A. It means, that the valve closes and cuts off the live steam from the boiler at 6 inches of the piston's travel, then the engine gets its power from the time the valve closes or cuts off, until the exhaust opens by the expansion of the steam closed up in the cylinder.

EXAMPLE:

Cylinder 12 x 24 in.	12	diam. of cylinder,
65 Revolution,	12	
Average Pressure 80 lbs.	144	sq. inch. in cylinder.
	.7854	
	113.0976	area of piston head face.
	80	average pressure.
	9047.8080	
	260	No. of ft. trav. by piston
33000)	2352430.0800	
	71.2857	Horse Power.

RULE for finding area of any diameter. Always multiply the diameter by itself, then by .7854, then cut off four decimals to the right.

RULE for finding the circumference of anything round. Multiply diameter by 3.1416 and cut off 4 decimals.

RULE. From ½ to ¾ square foot grate surface is allowed to a horse power of a boiler.

RULE to find how much water a boiler will contain. For 2 flue boiler ⅔ full of water; find ⅔ area of the boiler in inches inside; multiply by length in inches; then find area of flues, thickness of iron added; then multiply by 2, if two flues; multiply by length in inches, subtract area

of flues from ⅔ contents, and divide by 231 (number of cubic inches in standard gallon) the answer will be the number of U. S. standard gallons.

EXAMPLE:

Boiler 48 in.	48
Two Flues 16 in. each.	48
Length 20 ft.	2304
16	.7854
16	3)1809.5616 Area of Boiler.
256	603.1872 One-third of Area.
.7854	2
201.0624	1206.3744 Two-thirds "
2	240 Length in inches.
402.1248	289529.8560
240	96509.9520 Sub. Area of Flues.
96509.9520	231)193019.9040
	835.5840 No. of Gallons.

RULE to find the pressure on the crown sheet of a hanging fire box boiler. Multiply the width by the length in inches, then multiply by steam gauge pressure and divide by 2.

EXAMPLE:

Crown Sheet 46 x 33 in.	46
Pressure 85 lbs.	33
Iron ½ in.	1518
	85
If iron is ¼ in. div. by 4.	2)129030
" ⅝ in. div. by 2.66	2000)64515 lbs. pressure.
	32.257 Tons "

RULE to find quantity of water for a boiler for each horse power per minute. Add atmosphesic pressure to strain pressure; then divide by 18, multiply answer by .24, and that will give U. S. standard gallons per minute.

EXAMPLE:

One cubic foot of water is generally allowed for one horse power.

80 lbs. pressure.
15
18)95
5
.24
1.20=1⅕ Gallons.

RULE to find the amount of water required, when the average pounds of coal used per hour is known. Divide the coal by 7.5 the answer will be cubic feet, then multiply by 7.5 and that gives the number of U. S. standard gallons.

EXAMPLE:

117 lbs. of Coal used per hour,

7.5)117.0
15
7.5
112.5=112½ Galls.

Q. How many cubic feet in 1 lb. of air?

A. 13.817 cubic feet.

Q. How much air does it take to consume 1 lb. of coal.

A. It takes 18 lbs or 240 cubic feet.

Q. How would you tell the amount of water any tank contained?

A. If the tank was large at the bottom and narrow at the top, lay the tank off in 10 parts from top to bottom, then take the diameter $\frac{4}{10}$ from the large end of tank, square it, then multiply by .7854 that gives the area, then multiply quotient by full depth of tank and divide by 1728 which gives the number of cubic feet, multiply answer by 7.5 and the number of U. S. gallons will be given. The example must be done in inches, 1728 is the number of inches in a cubic foot, and 7.5 is the number of gallons in a cubic foot.

EXAMPLE:

Tank 2 ft. diam.
" 3 ft. deep,

24 diam.
24 "
576
.7854
452.3904 area,
36 in. depth.
1728)16286.0544
9.4248 cubic ft.
7.5 No. Galls. of cub. ft.
70.68600 U. S. Galls. in tank.

RULE for chimneys. Chimneys should be round inside, instead of square, to insure a good draft. The opening should be one-fifth larger than the area of the flues or tubes combined; if less, the draft will not be free. The opening from the bottom should increase in size to the top, and be as smooth as possible inside.

RULE for making good Babbitt metal, for high and low speed, in parts.

HIGH SPEED.		COMMON.		MEDIUM.	
10	Martins Nickle	12	Copper.....	60	Copper.....
16	Copper.....	4	Antimony.....	25	Antimony....
4	Antimony....	84	Tin.....	15	Tin.....
70	Tin.....				
100		100		100	

RULE for babbitting a box. Nearly every engineer has his own way; but the best and quickest way, is to chip out all the old babbitt in the cap and box, then put the journal or shaft that is to run in the box, in its place; put enough liners in between the shaft or journal and edge of box until level, square and in line; put thick putty around the shaft and against the box, so the babbitt cannot run out;

then heat the babbitt until it runs free, and pour accordingly; the cap is then bolted in its place upon $\frac{1}{16}$ in. thick liner, and putty placed as before, then pour the metal through the oil holes, which will have to be drilled out afterwards.

RULE for finding size of pulleys for the governor. For diameter of governor pulley, multiply the number of revolutions of engine by diameter of engine shaft pulley and divide by revolutions of governor.

RULE to find the diameter of engine shaft pulley, multiply the revolutions of governor by diameter of governor pulley, and divide by revolutions of the engine.

RULE to determine the capacity of any size pump, single or double action. Multiply the area of the water piston-head face or plunger in inches, by its stroke in inches, which gives the number of cubic inches per single stroke; the answer divided by 231 (the cubic inches in a gallon) will give the number of standard gallons per single stroke. But remember, all pumps throw less water than their capacity, which depends upon the condition and

quality of the pump. This loss arises from the rise and fall of the valves; from a bad fit or leakage; and in some cases from their being too much space between the valves, piston or plunger. The higher the valves have to rise to give the proper opening, the less work the pump will perform.

Q. Will a boiler 60 in. diam. ⅜ in. iron, stand as much pressure as a boiler 48 in. diam. ⅜ in. iron? A. No.

Q. Why? A. Because the pressure in the large boiler has more surface, and will not allow it. It is the same as a long bar and a short bar of the same thickness, it takes less strain to break the long one than the short one.

RULE for finding safe working pressure of steam boilers. Always use .56 for single riveted and .70 for double riveted. A radius means one-half the diameter; and one-fifth of tensile strength is the safe load. U. S. standard is one-sixth.

Multiply the thickness of iron by single or double rivets, then multiply by the safe load, divide by internal radius and the answer will be the safe working pressure.

EXAMPLE:

Diameter 42 in. .1875 thickness of iron,
Iron $\frac{3}{16}$ in. .70 double riveted,
Double rivetted and .131250
50,000 lbs. tensile strength. 10000 2)42
20.8125)13125000.00 21 outside radius.
Safe working pressure. 63.06 .1875
5 20.8125 inside rad.
Bursting Pressure. 315.30

RULE to find aggregate strain caused by the pressure of steam on the shells of boilers. Multiply the circumference in inches by the length in inches; multiply this answer by the pressure in pounds. The result will be the pressure on the shell of boiler, and divide by 2000 which gives the tons. EXAMPLE:—Diam. of boiler 48 in., circumference 150.7968, length 20 ft. or 240 in., pressure of steam 120 lbs.

150.7968 x 240 x 120 = 4342947.8400 lbs. ÷ 2000 = 2171½ tons strain.

RULE to find the number of feet of 1 in. pipe required to heat any size room with steam. For direct radiation 1 lineal foot (straight foot) to 25 cubic feet of space. For indirect radiation, 1 lineal foot to 15 cubic feet of space. Note all pipe is measured inside for size.

EXAMPLE:

Room 18 x 18 x 18 to be heated with 1 inch Pipe. Direct Radiation. All calculating must be done in inches, and divided by 1728 to give the cubic feet.

216
216
46656
216
1728)10077696 cubic inches.
25)5832 cubic feet:
Lineal $233\frac{7}{25}$ ft. of 1 inch pipe.

One cubic foot of boiler is required, for every 1500 cubic feet of space to be warmed. One horse power of boiler is enough for 40000 cubic feet of space.

RULE to find the horse power of a boiler. Always find the number of square inches and divide by 144, which gives the square feet of heating surface, and divide by 15 sq. ft. which is allowed for one horse power of a boiler; divide the H. P. by 2, you will have the proper grate surface, and allow ½ sq. in. of safety valve to 1 sq. ft. of grate surface.

EXAMPLE:

Boiler 48 in. x 25 ft. Two 16 in. Flues.

48 diam. of shell.
3.1416
3)150.7968
50.2652 ⅓ circumference.
2
100.5304 ⅔ "
300 length of boiler in inches.
30159.1200 No. sq. ft. heat. surf. in the shell.

48
48
2304
.7854
3)1809.5616 area of 1 head.
603.1872 ⅓ area of 1 hd.
2
1206.3744 ⅔ area of 1 hd.
2
2412.7488 ⅔ area of both heads.

First find the circumference of boiler.

16 diam. of 1 flue.
3.1416
50.2656 circ. of 1 flue.
300 length of flue in
15079.6800 inches.
2
30159.3600 heat. surf. 2 flues

16 diam. of 1 flue.
16
256
.7854
201.0624 area of 1 flue.
2
402.1248 area of 2 flues.
2
804.2496 both ends.

No. square feet of heating surface in the shell, 30159.1200
" " " " " flues, 30159.3600
Two-third area of both heads. 2412.7488
Total, 62731.2288
Subtract area of flues, 804.2496
144)61926.9792
15)430.
Horse Power,..... 2)28.
Grate Surface,..... 2)14.
Area of Safety Valve,..... 7.

RULE to find the horse power generated in any kind of boiler when running. First, notice how long it will take to evaporate one inch of water in the glass-gauge, divide this into 60, which gives the number of inches evaporated in one hour; second, multiply the average diameter where evaporation took place, by the length of the boiler in inches, this multiplied by the number of inches evaporated, and the answer divided by 1728 gives the cubic feet of water evaporated in one hour.

As a rule one cubic foot of water evaporated, is generally allowed for one horse power; also the capacity of a pump or injector for any boiler should deliver 1 cubic foot of water each horse power per hour.

EXAMPLE:

Length of Boiler 216 in.
Average Diam. 40 "
One inch evaporated in 15 minutes.

15)60
4

216
40
8640
4
1728)34560
20 horse power.

RULE to find the surface of a sphere, globe or ball.

EXAMPLE:—9 in. diam. x 3.1416=28.2744 x 9=254.4696 x 9=2290.2264÷6=381.⅔ solid contents.

RULE to find the solid contents of a sphere. Multiply cube of the diameter by .5236, the answer equals its solid contents.

EXAMPLE:—Sphere 3 in. diam. 3 x 3=9 9 x 3=27 x .5236=14.1372 solid contents.

RULE for safety valves. To find the distance P. should be placed on lever, when the weight is known, or the distance is known and weight is not known. Multiply the pressure required by area of valve, multiply the answer by the fulcrum; subtract the weight of the lever, valve and stem, and divide by the weight of P. for distance, or divide by distance for the weight of P. with same example as above.

EXAMPLE:

Weight of P.	60 lbs.	100 lbs. pressure.
Pressure,	100 "	3 area of valve.
Wt. of L.V. & Stem,	30 "	300
Fulcrum,	4 inch.	4 fulcrum.
Area of Valve,	3 "	1200
		30 wt. of L. V. & Stem.
N. B.) P. means the weight on the end of lever.		60)1170
		19½ in. P. should be hung on lever.

The mean effective weight of valve, lever and stem is found by connecting the lever at fulcrum, tie the valve-stem to lever with

a string, attach a spring scale to lever immediately over valve, and raise until the valve is clear of its seat, which will give the mean effective weight.

RULE for figuring the safety valve, when the area of valve, the weight of lever and valve are known, the distance fulcrum is from valve, and weight of P. is known.

EXAMPLE:

Weight of P.	50 lbs.	2.25	4)20
Wt. of L.V. & Stem,	30 "	2.25	5
Fulcrum	4 in.	5.0625	50
Diam. of Valve,	2¼ "	.7854	250
Length of Lever,	20 "	3.97608750 area.	30
Add as many cyphers to the dividend as there is decimals in the divisor, and divide as whole numbers.			3.9)280.0 lbs. press. $71.\frac{31}{39}$

To measure or mark off the lever, you measure the fulcrum and make marks the same distance as fulcrum; if fulcrum is 4 inches, each space must be 4 inches apart.

Q. What is meant by a fulcrum?

A. The distance valve stem is from where the lever is connected.

THE END.

CONTENTS.

MULTIPLICATION TABLE.

1 x 1 — 1	2 x 1 — 2	3 x 1 — 3
1 x 2 — 2	2 x 2 — 4	3 x 2 — 6
1 x 3 — 3	2 x 3 — 6	3 x 3 — 9
1 x 4 — 4	2 x 4 — 8	3 x 4 — 12
1 x 5 — 5	2 x 5 — 10	3 x 5 — 15
1 x 6 — 6	2 x 6 — 12	3 x 6 — 18
1 x 7 — 7	2 x 7 — 14	3 x 7 — 21
1 x 8 — 8	2 x 8 — 16	3 x 8 — 24
1 x 9 — 9	2 x 9 — 18	3 x 9 — 27
4 x 1 — 4	5 x 1 — 5	6 x 1 — 6
4 x 2 — 8	5 x 2 — 10	6 x 2 — 12
4 x 3 — 12	5 x 3 — 15	6 x 3 — 18
4 x 4 — 16	5 x 4 — 20	6 x 4 — 24
4 x 5 — 20	5 x 5 — 25	6 x 5 — 30
4 x 6 — 24	5 x 6 — 30	6 x 6 — 36
4 x 7 — 28	5 x 7 — 35	6 x 7 — 42
4 x 8 — 32	5 x 8 — 40	6 x 8 — 48
4 x 9 — 36	5 x 9 — 45	6 x 9 — 54
7 x 1 — 7	8 x 1 — 8	9 x 1 — 9
7 x 2 — 14	8 x 2 — 16	9 x 2 — 18
7 x 3 — 21	8 x 3 — 24	9 x 3 — 27
7 x 4 — 28	8 x 4 — 32	9 x 4 — 36
7 x 5 — 35	8 x 5 — 40	9 x 5 — 45
7 x 6 — 42	8 x 6 — 48	9 x 6 — 54
7 x 7 — 49	8 x 7 — 56	9 x 7 — 63
7 x 8 — 56	8 x 8 — 64	9 x 8 — 72
7 x 9 — 63	8 x 9 — 72	9 x 9 — 81